The Red Flag Threat Index

Murdoch and Gitro (2010) introduced the Red Flag Threat Index (RFTI) as a simple index derived from expected relative humidity and wind speed values to quantify the severity of critical fire weather condition. The index was modeled after the Haines Index (Haines 1988), in that it used meteorological variables to rate fire danger independently of fuels. The Haines Index, however, assesses risk based on temperature-dewpoint depressions and lapse rates, and is thus primarily an indicator for plume-driven wildfires. In the Great Plains, relative humidity and wind speed are the most commonly used predictors for wind-driven grassland fires.

In 2011, Murdoch, Gitro, Lindley, and Vitale began work to make the RFTI more robust and to demonstrate the adaptability of the index for use in any climate regime subject to wind-driven fires in fine fuels. This effort involved statistical analyses of approximately 2,300 critical fire weather observations across west Texas and application of the index to a dataset of proximity observations for 99 significant wildfire starts within the West Texas Mesonet (WTM) domain (Lindley et al. 2011). The resultant modified version of the RFTI provides a simple numerical and categorical rating which quantifies the fire weather threat posed by combinations of relative humidity and wind speed with respect to local climatological significance and past large wind-driven grassland wildfires. During the historic Texas wildfire season of 2011, the RFTI was used with success by the Midland Fire Department as a strategic staffing-decision tool. They found that the use of the RFTI decreased their overstaffing during false alarm days of marginal Red Flag-weather, and they credit use of the index in their decision to increase staff levels by 20 firefighters on 24 May 2011 – prior to the damaging CEED Fire which impacted the city of Midland.

the CEED Fire crossing Loop 250 into the western parts of Midland on 24 May 2011

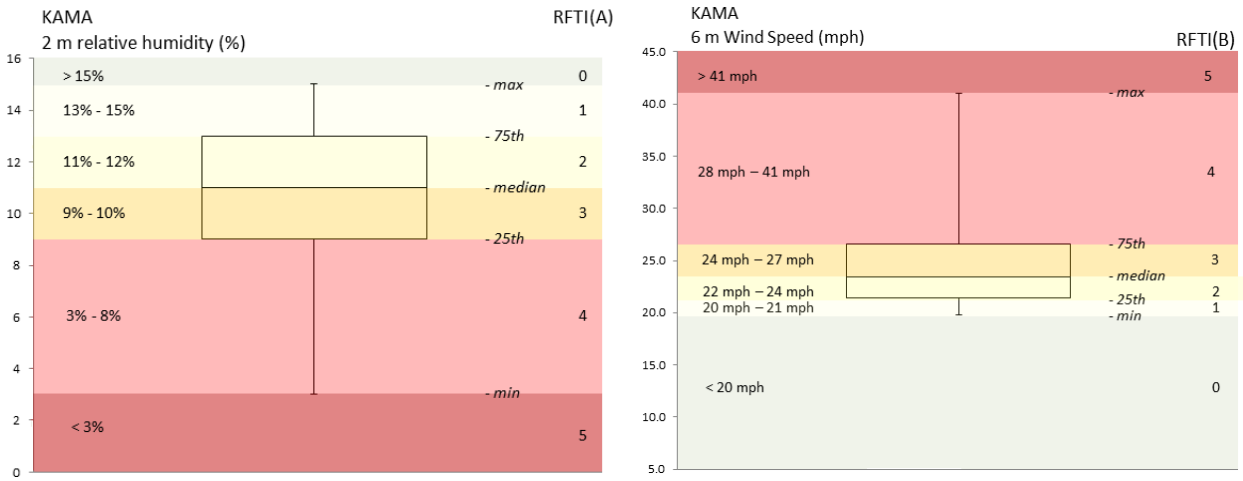
The RFTI and RFTI Cat are available in gridded format via GFE and are used operationally in the Fire Weather Point Forecast Matrices (PFW).

Index Derivation and Application –

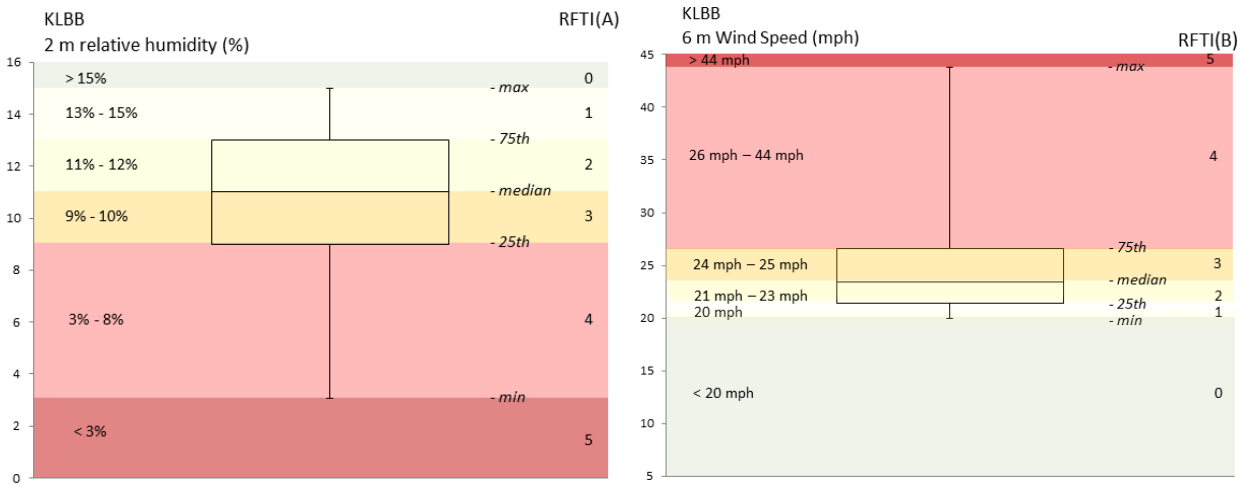
The RFTI is derived as the simple summation of a *relative humidity term RFTI(A)* and a *wind speed term RFTI(B).*

$$RFTI = RFTI(A) + RFTI(B)$$

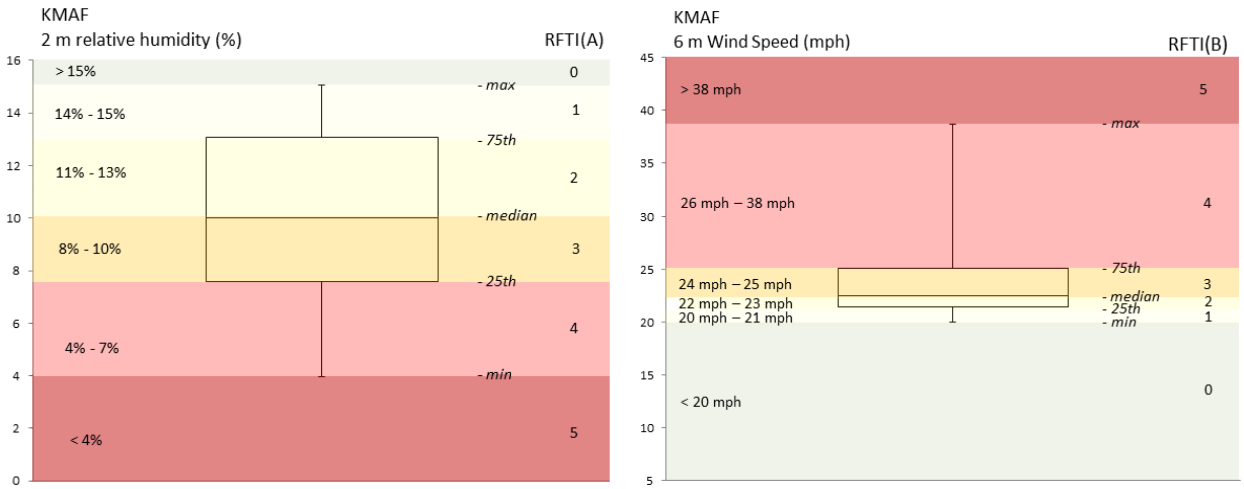
The RFTI(A) and RFTI(B) terms are based on statistical quartile rankings for a 10-year climatological database of critical fire weather observations, or observations exceeding the local Red Flag Warning criteria, at the location of interest. During the development of the RFTI, such climatological thresholds of 2-m relative humidity and 6-m wind speed were found at Amarillo (KAMA), Lubbock (KLBB), and Midland (KMAF) spanning 2000-2009. Note, 10-m observed wind speeds were reduced to 6-m via a 0.886 factor as observed by the WTM at Reese Center during diurnal burn periods (Lindley et al. 2011).



climatological quartile rankings and RFTI(A) and RFTI(B) terms at Amarillo (KAMA)

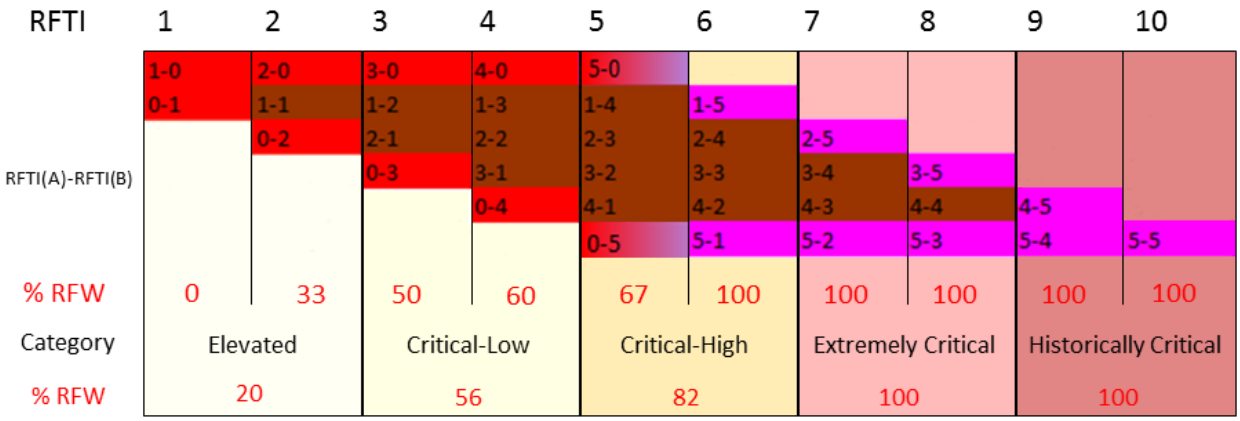


climatological quartile rankings and RFTI(A) and RFTI(B) terms at Lubbock (KLBB)



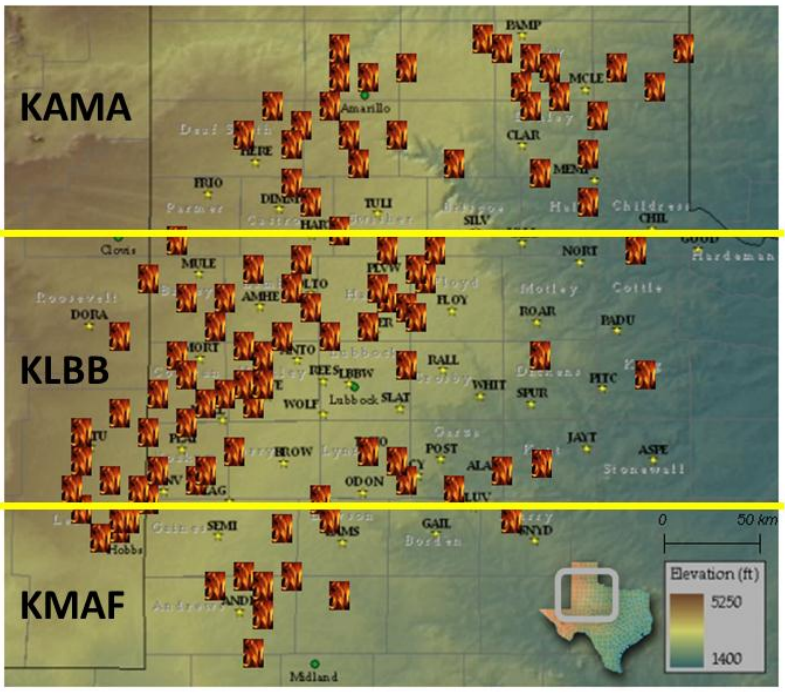
climatological quartile rankings and RFTI(A) and RFTI(B) terms at Midland (KMAF)

RFTI values, summed from the RFTI (A) and RFTI (B) terms for a particular observation site, were separated into "categories" that describe the wildfire threat/severity of critical fire weather associated with each score. The RFTI matrix below shows how differing combinations of RFTI (A) and RFTI (B) can result in specific non-zero RFTI values, their categorical description, and their relation to Red Flag Warning (RFW) criteria. In the matrix, RFTI scores that result from a non-zero value for only one term are shown in red, and these represent non-RFW conditions. More critical combinations of relative humidity and wind speed that meet RFW criteria with non-zero values for RFTI (A) and RFTI (B) are shown in maroon. Matrix cells that contain RFTI (A) and RFTI (B) combos inclusive of either a relative humidity, wind speed, or both parameters in excess of the 10-yr climatological dataset are shaded purple, and should be considered extremely rare. A RFTI ≥ 6 represents a 100% probability of RFW conditions.



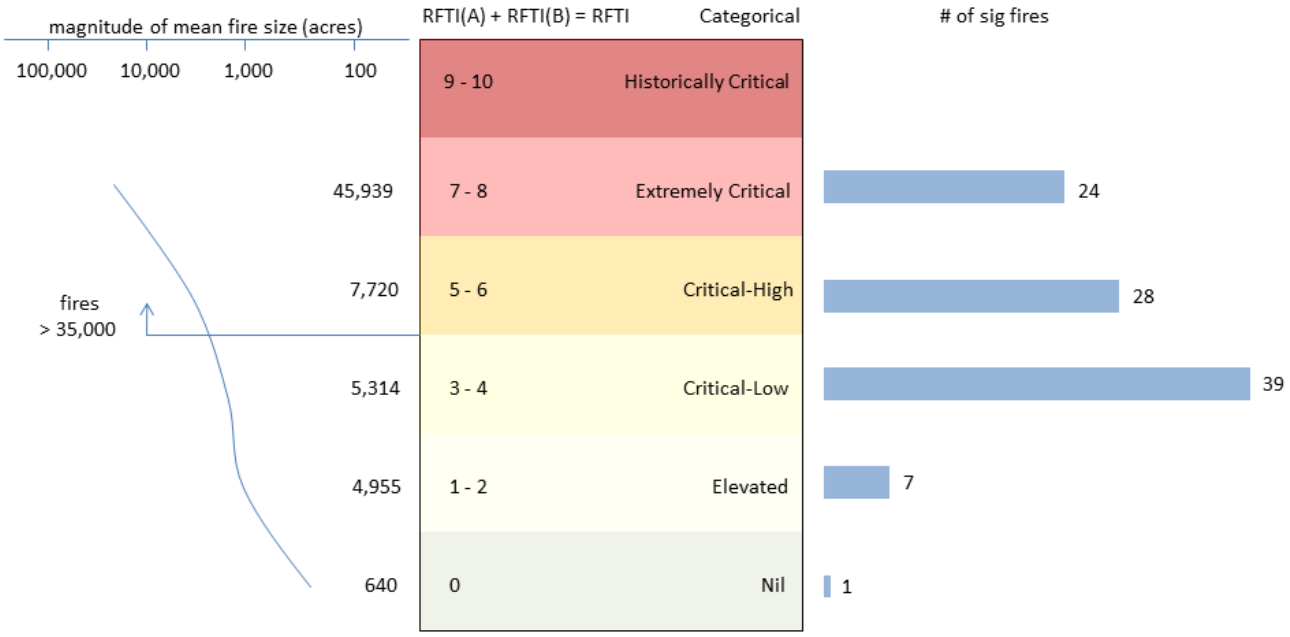
matrix showing combinations of RFTI (A) and RFTI (B) for each RFTI value, category, and relationship to RFW criteria. Red cells = non-RFW, maroon cells = typical RFW conditions, purple cells = very rare term values outside a 10-yr climatological database

In order to investigate the RFTI's relevance to west Texas wildfire environments, the index was applied to the Lindley et al. (2011) dataset of 99 proximity meteorological observations for significant wind-driven grassland wildfire starts within the WTM domain. The dataset, composed of wildland fire starts that grew to consume burn areas ≥ 300 acres spanning the 2006-2010 fire seasons, was differentiated spatially so that each fire start would be compared to the appropriate climatological thresholds for the nearest site, either KAMA, KLBB, or KMAF.



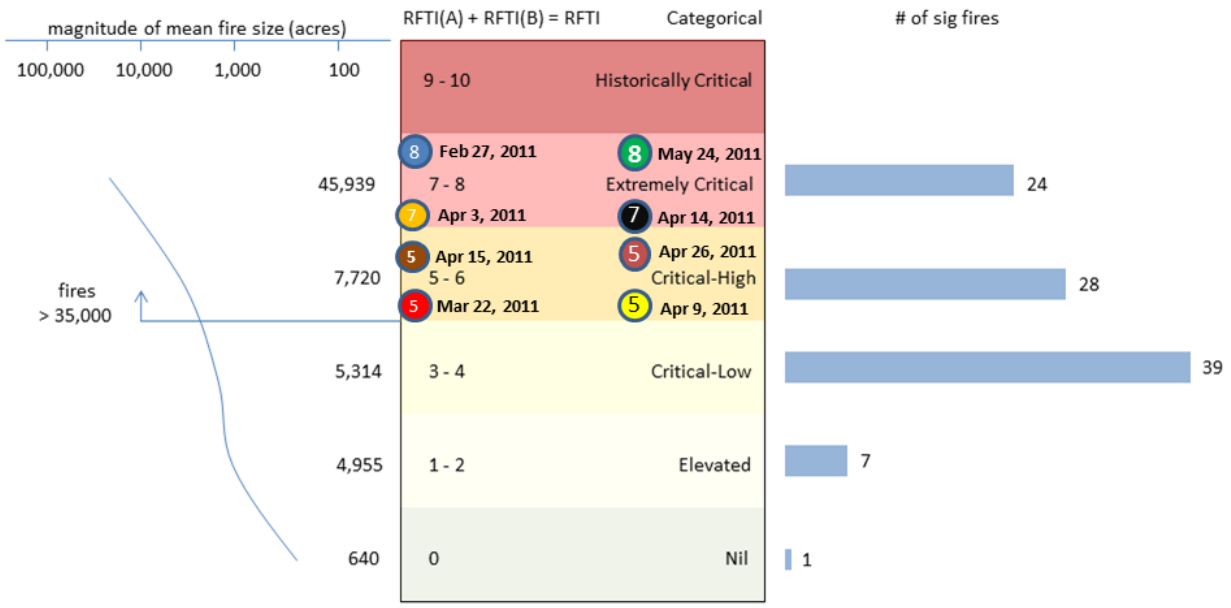
Lindley et al. (2011) wildfire start dataset shown as applied to the appropriate climatological quartiles for critical fire weather at KAMA, KLBB, and KMAF

Application of the Lindley et al. 2011 significant fire start dataset to the climatological quartiles for critical fire weather across west Texas reveals several useful applications. First, the number of significant fire starts per RFTI rating approximates a normal distribution centered on the Critical-Low and Critical-High RFTI values of 3-6. Secondly, the average fire size in each RFTI category generally increases with increasing RFTI values, and all fires that grew to consume > 35,000 acres occurred with RFTI values ≥ 5. Also, only one fire of 640 acres occurred with a RFTI = 0. No fires occurred in environments that exceeded the 10-year climate database of observations for either 2-m relative humidity and 6-m wind speed, however, such high-end values should not be discounted and corresponding RFTI values of 9 (one parameter exceeding 10-yr extremes) and 10 (both parameters exceeding 10-yr extremes) have been assigned the categorical rating "Historically Critical".



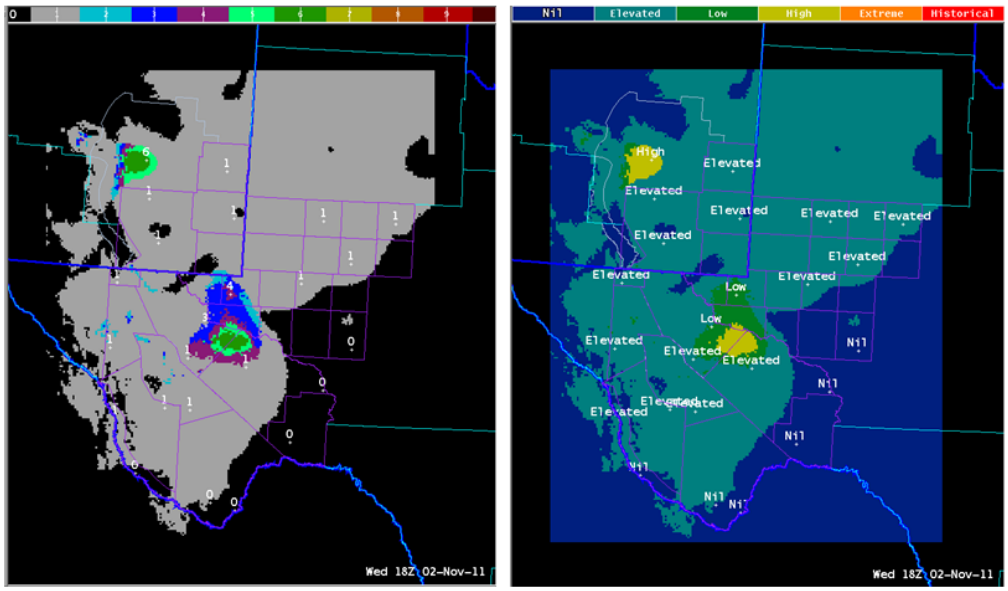
Application of the Lindley et al. (2011) wildfire start dataset to 10-year climatological quartiles for critical fire weather across west Texas

For use in this document, the Lubbock (KLBB) RFTI was applied to the February-May 2011 Southern Plains wildfire outbreaks. All of the outbreak days had a maximum RFTI ≥ 5 (Critical-High). Arguably the days with the most significant impacts to the Lubbock-area proper, 27 February (central Lubbock fire) and 24 May (Reese Center fire) correspond to RFTI = 8 (Extremely Critical).



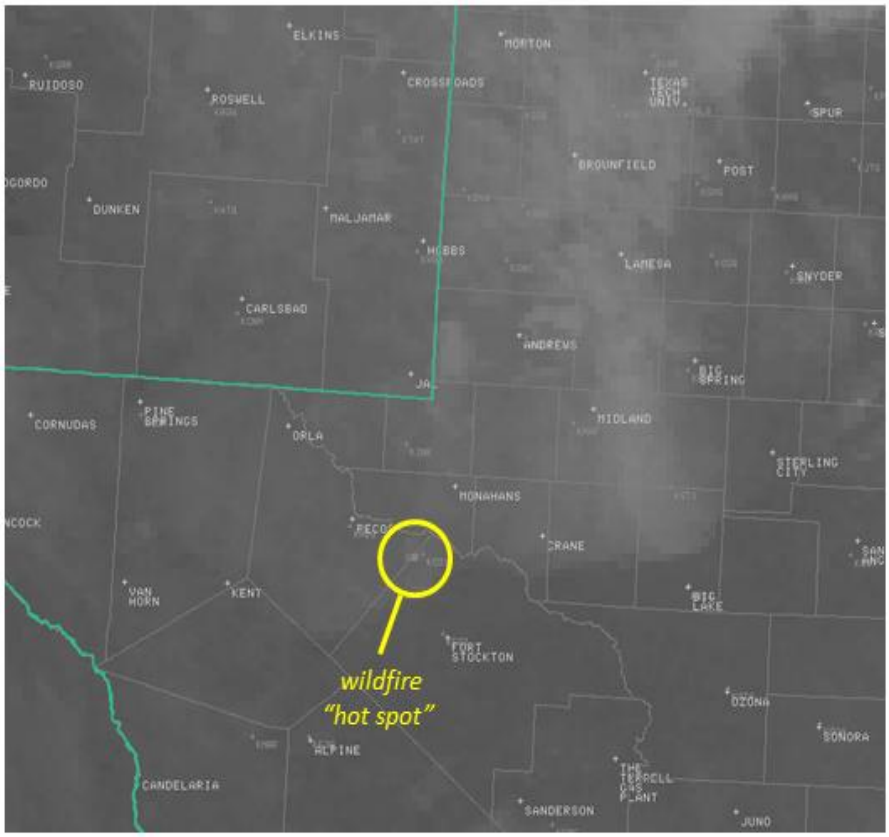
Lubbock (KLBB) RFTI values for the February-May 2011 Southern Plains wildfire outbreaks

A recent example which illustrates use of the RFTI from 2 November 2011 is shown below. In this example, KMAF RFTI values of 6 (Critical-High) were briefly forecast over portions of the Upper Trans Pecos at 1800 UTC when 2-m relative humidities were expected to drop into the mid-teens immediately south of advancing cold frontal passage which would bring an abrupt wind shift and sustained 6-m winds approaching 30 mph. Meanwhile, most of the remaining areas of west Texas were forecast to receive strong northerly winds but cooler temperatures and higher relative humidity – thus resulting in KLBB and KMAF RFTI values of 1 (Elevated).



KMAF RFTI forecast grids in GFE for 1800 UTC 2 November 2011

At approximately 1900 UTC a wildfire "hot spot" was detected in 11-3.9 micron satellite imagery just as the cold front swept through the area of critical fire weather. The WTM surface observation from Coyanosa at 1900 UTC recorded a 2-m relative humidity of 14% (RFTI(A)=1) and 6-m wind speed of 28 mph (RFTI(B)=4) for an observed KMAF RFTI = 5 (Critical-High).



11-3.9 micron satellite imagery 1900 UTC 2 November 2011

Conclusion –

The Red Flag Threat Index (RFTI) shows operational value as a decision tool which quantifies the fire weather severity relative to a statistical analysis of climatological critical fire weather independent of vegetative fuels. The RFTI is derived by scoring the statistical quartiles of approximately 2,300 critical fire weather observations across west Texas for 2-m relative humidity and 6-m wind speed in excess of local Red Flag Warning criteria. When applied to a pre-existing dataset of WTM proximity meteorological observations for 99 significant wind-driven wildfire starts, the distribution of fire start environments approximates a normal distribution relative to RFTI centered on values of 3-6 (Critical-Low and Critical-High). This distribution of RFTI scores shows minimal fire activity when neither 2-m relative humidity nor 6-m wind speed exceed critical thresholds (RFTI = 0), and as expected, no fires

within the database occurred with either 2-m relative humidity or 6-m wind speeds in excess of a 10-year climatology. Such rare and extreme values, however, should not be discounted and would be considered "Historically Critical". All fires that consumed burn areas ≥ 35,000 acres were associated with RFTI values ≥ 5. Also, each of the February – May 2011 Southern Plains wildfire outbreaks occurred during RFTI values ≥ 5 at Lubbock (KLBB). The outbreak days with the most significant local impacts at Lubbock occurred when the KLBB RFTI reached 8 (Extremely Critical).

References –

Haines, DA, 1988: A Lower Atmosphere Severity Index for Wildland Fires. *National Weather Digest* 13**,** 23-27.

Lindley, T. T., J. D. Vitale, W. S. Burgett, and M.-J. Beierle, 2011: Proximity meteorological observations for wind-driven grassland wildfire starts on the southern High Plains. Electronic J. Severe Storms Meteor., 6(1), 1-27

Murdoch, G. P., C. Gitro, 2010: Assessing critical fire weather conditions using a red flag threat index. 35th Annual Nat. Weath. Assoc. Meeting. Tucson, AZ.

Contact Information –

Greg Murdoch – NOAA/NWS Midland, Texas Gregory.Murdoch@noaa.gov

Todd Lindley – NOAA/NWS Lubbock, Texas Todd.Lindley@noaa.gov